

This report contains the collective views of an international group of experts and does not necessarily represent the decisions or the stated policy of the World Health Organization

Engineering aspects of vector control operations

First Report of the WHO Expert Committee
on Vector Biology and Control

World Health Organization
Technical Report Series
603



World Health Organization Geneva 1977

ISBN 92 4 120603 9

© World Health Organization 1977

Publications of the World Health Organization enjoy copyright protection in accordance with the provisions of Protocol 2 of the Universal Copyright Convention. For rights of reproduction or translation of WHO publications, in part or *in toto*, application should be made to the Office of Publications, World Health Organization, Geneva, Switzerland. The World Health Organization welcomes such applications.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

PRINTED IN SWITZERLAND

WORLD HEALTH ORGANIZATION
TECHNICAL REPORT SERIES

No. 603

**ENGINEERING ASPECTS
OF VECTOR CONTROL OPERATIONS**

**First Report of the
WHO Expert Committee on Vector Biology and Control**

CORRIGENDUM

Page 22, line 4

delete pressures above 6.5 kPa.

insert pressures above 300 kPa.

CONTENTS

	Page
1. Introduction	5
2. Pesticide application equipment—general considerations	5
2.1 Strategy	5
2.2 Equipment evaluation	7
2.3 Purchasing	8
2.4 Training	9
2.5 Management	9
3. Pesticide application equipment—problems and progress	10
3.1 Introduction	10
3.2 Hand compression sprayers	11
3.3 Motorized knapsack mist blowers	12
3.4 Aerosol generators	13
3.5 Aircraft equipment	15
4. Non-chemical control measures	18
4.1 Biological control measures	18
4.2 Environmental measures	19
5. Safety considerations	20
5.1 Chemical control measures	21
5.2 Non-chemical control measures	23
6. Transport in vector control operations	23
6.1 Wheeled vehicles	24
6.2 Boats	26
6.3 Air-cushion vehicles	26
6.4 Aircraft	26
7. Specifications	27
8. Recommendations	28
Acknowledgements	31
Annex 1. Outline of WHO Pesticide Application Equipment Evaluation Scheme	32
Annex 2. Revised specification for compression sprayer, hand-operated	33
Annex 3. Effect of national water management policies on vector populations in Israel	39
References	40

WHO EXPERT COMMITTEE ON VECTOR BIOLOGY AND CONTROL

Geneva, 7-13 September 1976

Members :

- Professor N. B. Akesson, Department of Agricultural Engineering, University of California, Davis, CA, USA (*Chairman*)
- Mr S. Arlosoroff, Deputy Water Commissioner, State of Israel Water Commission, Tel-Aviv, Israel
- Dr Boonluan Phanthumachinda, Division of Medical Entomology, Department of Medical Sciences, Bangkok, Thailand (*Vice-Chairman*)
- Mr C. W. Lee, Scientific Secretary, Centre for Overseas Pest Research, College House, Wrights Lane, London, England (*Rapporteur*)
- Dr M. Privora, Institute of Hygiene and Epidemiology, Prague, Czechoslovakia
- Dr B. Sánchez Díaz, Chief, Vector and Reservoir Control Department, Ministry of Health and Social Assistance, Maracay, Aragua, Venezuela
- Dr T. Takenaga, Institute of Agricultural Machinery, Saitama-ken, Japan
- Mr C. S. Tarimo, Deputy Director, Tropical Pesticides Research Institute, East African Community, Arusha, United Republic of Tanzania

Representatives of other organizations :

- Mr A. Adam, Pesticides Officer, Plant Production and Protection Division, Food and Agriculture Organization of the United Nations, Rome, Italy

Secretariat :

- Dr N. G. Gratz, Chief, Ecology and Control of Vectors, Division of Vector Biology and Control, WHO, Geneva, Switzerland (*Secretary*)
- Dr G. A. Matthews, Overseas Spraying Machinery Centre, Imperial College Field Station, Silwood Park, Ascot, Berkshire, England (*Temporary Adviser*)
- Dr G. A. Mount, Research Entomologist, Insects Affecting Man Research Laboratory, United States Department of Agriculture, Gainesville, FL, USA (*Temporary Adviser*)
- Mr J. D. Parker, Equipment, Planning and Operations, Division of Vector Biology and Control, WHO, Geneva, Switzerland

ENGINEERING ASPECTS OF VECTOR CONTROL OPERATIONS

First Report of the
WHO Expert Committee on Vector Biology and Control*

1. INTRODUCTION

The WHO Expert Committee on Vector Biology and Control met in Geneva from 7 to 13 September 1976 to discuss equipment for the application of pesticides and other engineering aspects of vector control programmes. Dr N. G. Gratz, Chief, Ecology and Control of Vectors, opened the meeting on behalf of the Director-General. He said that, since the last meeting of an expert group on this subject, in 1970 (1), there had been many advances in the technology of pesticide application equipment for the control of vectors of human disease. The Committee was therefore being asked to re-evaluate the role of WHO in the development and use of such equipment. They should consider the safety aspects and transport requirements of vector control operations as well as specific problems of application equipment. In addition, he requested the Committee to discuss certain aspects of environmental management and biological methods of vector control.

2. PESTICIDE APPLICATION EQUIPMENT— GENERAL CONSIDERATIONS

2.1 Strategy

New and more efficient pesticide application equipment is needed in vector control programmes to reduce costs and improve control strategies. Hand-operated compression sprayers have been widely used to apply residual deposits of persistent insecticides to walls of dwellings. Such applications are not always successful, and other application techniques are sometimes required. In addition, the effective integration of chemical and non-chemical methods of vector control is desirable in some instances (see section 4).

Fixed schedules and dosages for treatments, although useful operational guides in the past, should now be replaced wherever possible by

* This committee replaces the former WHO Expert Committee on Insecticides.

flexible programmes of chemical treatment aimed at specific targets for disease control or prevention. Determination of the optimum droplet size of sprays and use of equipment producing droplets within narrow size-ranges for these targets will increase the biological effectiveness of insecticides, reduce the doses required, and thereby minimize environmental contamination. The appropriate droplet size-range depends on whether the strategy is to apply larvicides or imagicides and, if the latter, on whether imagiciding is to be done by a space application or by residual treatment of preferred resting sites. Thus the choice of strategy will depend largely on the behavioural characteristics of the target vector. However, it may be anticipated that carefully timed sequential treatments of non-persistent insecticides will come into greater use. Such treatments need to cover a sufficiently large area in a short time so as to avoid immediate reinfestation from neighbouring areas, but must be limited in time and space to minimize selection pressure for resistance.

The Committee noted that further research is required to determine the production and diffusion characteristics of droplets of various sizes released under differing weather conditions and in relation to droplet penetration through vegetation and into dwellings for the control of specific targets. This information, together with data on the susceptibility of vectors to insecticides, should aid rational selection of the strategy, including such factors as droplet size, application volume, insecticide concentration, and optimum weather conditions for insecticide application.

Aerial applications of aerosols at very low dosage rates have been effective in space treatments for controlling tsetse flies; oil formulations of insecticides have been used in doses of approximately 10 g/ha. Similar applications of other formulations, including wettable powders and microencapsulated insecticides, should be investigated.

The effective use of aerosols outdoors is dependent on the correct timing of the application in relation to meteorological factors, as well as the flight behaviour of the vector. If applications are made in a light breeze, under temperature inversion conditions, the aerosol is dispersed yet droplets are retained within the habitat of the vector. In urban areas careful planning of treatments is essential, as the shape and layout of buildings considerably affect air movement, and this also applies to rural areas where vegetation in riverine situations and forest belts harbours vectors. Simultaneous use of both hand-carried and vehicle-mounted equipment may be needed in places where some sites requiring treatment are not accessible by road. Similarly, aerial applications may be supplemented by localized ground treatments.

The Committee suggested further research to develop a range of different types of equipment, from hand-carried machines to nozzles fitted to aircraft, by means of which droplet size could be controlled within very narrow limits. Consideration must be given to avoiding operator contamination, reducing power requirements, and minimizing losses to and contamination of the environment. The capital and recurrent costs of equipment, its robustness, and its ease of maintenance also need consideration.

Where alternative pesticide formulations are available, the least toxic to man and least hazardous to the environment should be given preference. A full cost/effectiveness analysis of the different application techniques available is also desirable, but not always practicable, before a particular strategy is selected.

2.2 Equipment evaluation

Once a decision has been made regarding the type of equipment required for a particular operation, the various makes and models available must be examined and, if possible, tested against a relevant performance specification. The following considerations apply to the evaluation and selection of pesticide application equipment.

- The suitability of the equipment for the kind of vector control operation to be undertaken ; both the type and size of equipment required must be considered.
- The availability of the model, spare parts, and servicing facilities in the programme area.
- The performance of the equipment in the workshop and field.
- The cost of the equipment, including the cost of spare parts in the programme area.

To evaluate application equipment properly, both workshop and field investigations are required. These should be coordinated by WHO and its collaborating centres.

For workshop evaluations, the specifications should be of the "performance" type as well as the "content" type (in which specific materials and dimensions are prescribed for equipment) and should be directly relevant to the particular vector control operations to be undertaken and to the conditions prevailing in the programme area.

Once equipment has been satisfactorily tested in the workshop, it should be evaluated in the field. Field evaluations are designed to

establish the suitability of the equipment for use in the programme area and to determine its effectiveness in controlling the vector. In this connexion, the Committee suggested that research should be carried out to improve methods and materials for assessing the effects of control operations on populations of arthropod vectors and in particular to develop better sampling techniques for the detection of low population densities.

An important component of both workshop and field evaluations is the feedback of the results obtained and suggestions for improvement to the manufacturer and to collaborating centres. This is one important way of obtaining improvements in the design and performance of pesticide application equipment. Experience has shown that much of the equipment produced does not reach a satisfactory engineering standard and that manufacturers frequently do not supply the purchaser with adequate instructions for the use, maintenance, and repair of their products.

Many pesticide formulations have a detrimental effect on equipment components and the Committee proposed that evaluation tests be made to determine what types of application equipment are most suitable for use with the various insecticide formulations.

Recognizing that there are many different types of pesticide application equipment throughout the world, the Committee agreed that some systematic process for equipment evaluation was required. The Committee approved such a scheme (outlined in Annex 1) and recommended that it be known as the "WHO Pesticide Application Equipment Evaluation Scheme". It is proposed that WHO, in coordination with FAO, should promote the implementation of this scheme.

2.3 Purchasing

Most types of application equipment are used in both agriculture and public health programmes, and the Committee therefore suggested that each country should develop a system for coordinating purchases of equipment selected to meet relevant performance specifications. Standardization of the equipment used in a given area could facilitate the development of sales and servicing facilities. Manufacturers or their agents should be responsible for ensuring a proper supply of spare parts, repairing initial faults under warranty as well as any damage caused by faulty packing for shipment, and assembling and testing equipment ready for use. It was reported that certain centralized agencies have now been set up that may be consulted in connexion with the production, evaluation, and purchase of equipment. The Committee recommended

that purchaser authorities should work in coordination with these agencies in order to obtain favourable price quotations from manufacturers.

Specialized equipment used solely in public health programmes could perhaps be purchased regionally through international agencies such as WHO and UNICEF. The Committee suggested that equipment users should actively participate in the improvement and development of application equipment by informing manufacturers of difficulties experienced during the use of equipment in the field.

2.4 Training

Many of the problems of poor operation and breakdown of application machines are due to inadequate instruction in the proper use and maintenance of equipment. Manufacturers' operating manuals are frequently inadequate in content and clarity and in most countries are not available in the local languages.

WHO should encourage the production of short manuals or brochures describing the various methods of application and types of equipment available for specific control programmes. Certain manuals should provide information appropriate for the sprayman and maintenance mechanic, the project supervisor, the project manager, and the purchasing agent. Other brochures, especially ones describing the use of equipment specifically for vector control programmes, would provide valuable information for the manufacturer, his development and sales personnel, and local representatives. For example, one brochure might be devoted to ground-operated machines used to apply insecticide aerosols for mosquito imagiciding programmes. Liberal use of diagrams and illustrations, including cut-away models of the machine, would be desirable.

The Committee suggested that training courses be organized for operators and mechanics and that training manuals in vernacular languages and other aids be developed in collaboration with manufacturers. Course instructors could make use of large diagrams and slide tape shows. A significant part of the training time should be devoted to field operations, fault-finding, and maintenance.

2.5 Management

Good management is crucial to the success of any vector control programme, from the initial planning and costing to the selection of suitable equipment and materials, training of personnel, the execution

of the programme, and its subsequent evaluation. The programme components that should be considered by the manager are as follows.

- Basic and practical training of programme staff at all levels, including managers, supervisors, and spraymen.
- Suitable maintenance and repair facilities; these should be included in the programme plan.
- Workshops staffed with trained personnel some of whom accompany spray teams to carry out minor adjustments and repairs in the field.

The programme manager is responsible for ensuring that an adequate supply of spare parts is included in the purchase of equipment and that spares are available whenever needed. Larger vector control operations may require the setting up of a supplies and distribution service to ensure the availability of equipment and spares.

3. PESTICIDE APPLICATION EQUIPMENT— PROBLEMS AND PROGRESS

3.1 Introduction

The Committee reviewed the various types of pesticide application equipment used in vector control operations, with special emphasis on the problems encountered in their use and the progress made recently in solving them. The most common type of hand-operated equipment is the hand compression sprayer used in malaria control programmes. If properly maintained, such equipment can give satisfactory service for 10 years or more under field conditions. However, there remain a few problems, even with the best models currently available (section 3.2).

It was noted that hand-operated application equipment is also used in tsetse fly control operations, especially in Nigeria, where control measures involve the application of residual-acting insecticides to the dry-season resting sites of the fly. For this work, pressure-retaining compression sprayers are preferred. Unfortunately, such equipment is not readily available at present.

Problems continue to occur with motorized pesticide application equipment. With the exception of a few types that might be considered suitable, the machines in use have one or more of the following faults:

1. Frequently, equipment is too heavy for convenient use, especially in areas where poor roads and tracks make it more difficult for equipment operators to handle heavy machines.

2. Fire is a hazard with equipment powered by internal combustion engines and has caused several accidents. The risk is particularly great with hand-carried or knapsack machines where fuel may spill from a poorly designed tank and ignite on contact with a hot exhaust system. When vehicle-mounted equipment is used, fire extinguishers should be carried at all times.

3. Insufficient robustness and durability in the construction materials used is a serious problem. The use of plastics to reduce weight is permissible only where the lesser strength of this material, as compared with that of metals, will not reduce the efficiency or effectiveness of the machine.

4. Vibration often causes discomfort to the operator, although this may be reduced by decreasing the engine speed.

5. The engine of motorized pesticide application equipment is frequently difficult to start. This problem can be minimized by ensuring that correct starting procedures and proper maintenance schedules are followed. These should be clearly indicated in manufacturers' operating manuals, which should contain details of both the engine and the sprayer.

It was recognized that equipment powered by internal combustion engines often becomes inoperative for various reasons. The Committee proposed that investigations should be carried out to develop other power sources for pesticide application equipment.

3.2 Hand compression sprayers

The Committee noted that very reliable hand compression sprayers are now available as a result of the manufacture of such equipment to Specification WHO/EQP/1.R3.^a Additional improvements have been made to these sprayers in response to field reports of weaknesses in some components. These improvements include a more robust pressure gauge, increased chemical resistance to certain solvents resulting from a change in the material used in the tank lid gasket, and a redesigned lower strap clip to avoid standing the sprayer on the strap.

The main fault with this type of equipment continues to be the decrease in pressure at the nozzle during spraying. The disc flow regulator has not been widely used by field workers. It was suggested that a robust regulator and pressure gauge should be developed to improve

^a A further revision of this specification was approved by the Committee (see Annex 2).

spraying efficiency and reduce operator contamination. Since certain components are subject to wear, a preventive maintenance routine should be followed by workshops and spray teams so that nozzle tips, seals, and valves are replaced in good time.

3.3 Motorized knapsack mist blowers

Motorized knapsack mist blowers are suitable for low-volume and ultra-low-volume (ULV) applications of insecticides whenever the droplets have to be projected away from the operator. The equipment can also be modified for dust and granule application. A 2-stroke internal combustion engine drives a centrifugal blower or fan to produce a high-velocity airstream into which pesticide chemical is introduced. Liquid is fed by gravity or small pump and passes via a trigger valve or tap through a metering orifice to the nozzle, where droplets are entrained in the airstream and projected from the outlet. Nozzles are of either the Venturi/shear or the rotary type.

This type of machine has been used extensively in crop protection and tsetse fly control and, during recent years, in some mosquito control operations. For tsetse fly control, several different models have been used to apply residual insecticides to resting sites of both riverine and savanna species, and great reductions in vector populations have often resulted within a short time. In West Africa this type of machine has been used in eradication programmes, and in East Africa mist blowers have also been used to apply non-residual insecticides, including ULV formulations.

Since 1970, *Aedes aegypti* has been controlled in urban areas of Thailand during outbreaks of disease borne by this vector. The technique has been to apply insecticide aerosols and mists to kill the infective mosquitos around and inside houses. The spray operator walks along the street directing the lance of the mist blower through the doors and windows to distribute insecticide within the rooms. There is a suggestion that larger droplets have given some residual effect.

With the increasing use of ULV applications and hence of motorized knapsack mist blowers, poor engine reliability has become a more prominent problem. Difficulties in starting 2-stroke engines and overheating are usually associated with poor routine maintenance, which in turn is partly due to inadequate training. Common faults include the use of an incorrect oil-fuel mixture, dirty sparking plugs, damaged recoil starters, and lack of maintenance on air cleaners and carburettors.

Some models are heavy and tend to tire the operator fairly quickly, and on occasions machines develop leakages at the insecticide and fuel taps. Control of throughput and droplet size also needs careful attention, especially when low volumes are applied. Changes in output may be due to the effect of chemicals, particularly certain solvents, on individual components, such as O-ring seals, or lack of sufficient pressure at the nozzle. To reduce the risk of breakdowns in the field, the effect of new formulations on the various materials used in the construction of these and other types of application equipment should be determined. The size of the insecticide and fuel tanks required depends on the application rates to be used and fuel consumption.

3.4 Aerosol generators

Aerosol application equipment is designed and constructed specifically for space treatments against adult mosquitos and other flying insects and has received increasing use in vector control programmes during recent years.

Vehicle-mounted aerosol generators are especially useful in reducing adult mosquito populations in urban and suburban areas having adequate access roads. They may be used in combination with knapsack and hand-carried aerosol generators in areas that cannot be fully covered by vehicle-mounted machines. In some areas, aerosol generators on vehicles have replaced high-volume thermal fogging machines in mosquito control programmes because they have several economic and environmental advantages. These include closer control of droplet size, leading to a better deposition on flying insects, and a reduction in the hazards to traffic often experienced with thermal fogging apparatus.

On the other hand, vehicle-mounted aerosol generators are heavy and expensive and cannot be used where there are no suitable roads or tracks. Most generators of this kind are not supplied with sufficient instruments to ensure that the equipment is working correctly, and the Committee suggested that this deficiency should be remedied.

Since portable aerosol generators often have a lower output than required and may be used around houses, it is desirable for them to be fitted with some form of blower so that aerosol droplets can be forced into buildings. Most portable aerosol generators are not supplied with blowers.

The optimum insecticide droplet size for the control of adult mosquitos has been found to be in the range of 10–20 μm volume median diameter (VMD). This degree of atomization can be achieved by means

of a vortical nozzle and the use of compressed air at 28–41 kPa pressure ^a and an insecticide flow rate of 30–450 ml/min. A second type of nozzle using air at 552–690 kPa and a flow rate of 90–130 ml/min has also been developed.

The Committee considered various aspects of aerosol-producing machines that make use of 2-fluid nozzles. It was agreed that the metering system should include a transparent flow meter and needle valve or other adjustable restrictor capable of accurately regulating insecticide flow rates of 30–600 ml/min. The flow meter and insecticide control valve should be mounted on a remote instrument panel placed in the vehicle cab. This panel should also contain separate gauges for monitoring nozzle air pressure and air volume and a thermometer for measuring the temperature of the insecticide as it passes through the flow meter. Where appropriate, there should be a gauge for monitoring insecticide tank air pressure.

All components of the flow metering system that come into contact with the insecticide should be constructed of corrosion-resistant materials such as glass, polyethylene, polytetrafluoroethylene, nylon, and stainless steel.

The engine in vehicle-mounted machines should have sufficient power to operate the pump or compressor without undue strain; overloading shortens the operational life of the engine. The actual engine size required will depend upon the pump or compressor design and the type of nozzle.

Aerosol generators using air shear nozzles should be fitted with reciprocating pumps to supply air pressures of at least 690 kPa to the nozzle system. The pump should also supply pressures of 83 kPa or more to the insecticide tank.

Air for vortical nozzles is furnished by rotary compressors. These compressors should provide at least 41 kPa to the nozzle.

Persons working in close proximity to these machines, especially for long periods, should wear ear protectors because of the level of noise produced. The generator should be capable of being easily lifted on and off the vehicle, and lightweight metals should be used in construction whenever possible.

For adequate coverage inside open houses and other buildings in domestic mosquito control programmes, vehicle-mounted equipment should be capable of discharging an aerosol cloud to either side of the

^a In accordance with international recommendations pressures are expressed here in pascals, the SI unit. Conversion factors are as follows: 1 pascal (Pa) = 1 newton per square metre (N/m²) = 0.145×10^{-3} pound-force per square inch (lbf/in²); 1 lbf/in² = $6.894\ 76 \times 10^3$ Pa.

vehicle. The discharge should extend 8 m or more during relatively calm winds to ensure thorough coverage.

Outdoor space treatments are usually made at 100–200 m swath intervals, achieved by wind dispersal of the aerosol cloud. Drift is dependent upon natural wind currents, and swath widths of 200 m or more can be achieved but only under favourable weather conditions.

The Committee discussed the importance of the insecticide droplet size used in aerosol and spray applications as regards both the calibration of machinery and the evaluation of spraying techniques. It was agreed that, although there are many different methods and materials for droplet evaluation, the method described by the WHO Expert Committee on Insecticides (1) is still the most satisfactory and practical one for workers in the field.

A sedimentation method for sampling aerosol droplets in rooms, using them as settlement chambers, was reported to the Committee. The method, which is suitable only for non-volatile formulations, is described below.

A sedimentation method for sampling droplets from aerosol generators applied to rooms. Collections can be made in the following manner :

(a) Place a glass slide coated with MgO on the floor of the room, making sure that the room is relatively airtight and that there are no air currents.

(b) Turn the aerosol nozzle so that the discharge will be directed through a door or window into the room.

(c) Move the generator past the opening at operational speed.

(d) Close the window or door of the room.

(e) Allow 2 hours for settlement of the aerosol droplets on to the glass slide.

Measurement and calculation of droplet size can then be made according to the methods described in an earlier report (1).

The Committee considered that further research is needed to develop simple and inexpensive droplet size monitoring techniques suitable for field use, especially for sampling droplets in the aerosol size range.

3.5 Aircraft equipment

Aircraft continue to play a significant role in the application of pesticides in vector control programmes. Aircraft can also be used to provide a rapid insecticide application in the event of an epidemic of

vector-borne disease. Applications of aerosols from fixed-wing aircraft have been effective in the control of several disease vectors, as discussed below, but the Committee suggested that equipment should be developed for aerosol production from helicopters, as in some situations downwash from the rotor blades may improve the distribution of the insecticide. Furthermore, helicopters may be more readily available than fixed-wing aircraft in emergencies.

Mosquito control programmes are being carried out in many parts of the world, both on a routine basis and in emergency situations. Aircraft can be most effective during outbreaks of vector-borne disease such as have occurred in various parts of Asia, Africa, and South America. Encephalitis outbreaks in the USA have been alleviated in recent years by aircraft spray programmes designed to control the vector mosquito species.

Granulated (non-dusting) chemicals and large-droplet sprays are most satisfactory for mosquito larviciding applications into water or wherever a residual deposit of chemical is desired. In general, aerial spraying produces a broad spectrum of droplets within the mist and fine-spray range. This can be effective both as a space spray, for direct contact on insects, and as a residual acting application, by the deposition of the larger droplets.

Aircraft are not widely used in developing countries in mosquito control programmes, except during emergency vector-borne disease epidemics. Various types of application equipment are in use, including boom-and-nozzle, rotary atomizer, and thermal exhaust systems. For aerosol production, the rotary atomizer system is the most suitable but the equipment is expensive to purchase and fit on the aircraft and, with slow flying aircraft, it will not produce the right droplet size for efficient mosquito control.

The Committee reviewed the use of aircraft for emergency mosquito-borne disease control and noted that, although aircraft of various types were often available, the required application equipment was frequently lacking.

Tsetse fly control programmes using aircraft have increased in importance during the last decade. Fixed-wing aircraft are used extensively to make sequential applications of aerosols (25–30 μm VMD) using twin-engined aircraft fitted with wind-driven rotary atomizers and flying at speeds of about 250 km/h. These greater flying speeds have made it possible to increase both the speed of rotation of the atomizers and

the shearing forces on the droplets released, which results in smaller droplets than could be produced in the past.

Helicopter spraying techniques based on the use of electrically driven spinning devices to apply sprays of persistent insecticides have been developed in Nigeria for the control of flies in savanna woodland and riverine forest habitats in which it is difficult to use ground spraying techniques. The choice of a particular technique has been determined to a large extent by the nature of the habitat and the topography of the land. It may also have been influenced by traditional methods of tsetse fly control, such as discriminative and selective ground spraying, which in Nigeria have been developed to a high degree of efficiency (2).

The equipment used for insecticide applications from helicopters for residual spraying needs to be improved so that environmental contamination is reduced while more effective deposition of small droplets within the tsetse fly habitat is achieved. Simple and inexpensive equipment is also needed to produce aerosol droplets from helicopters and fixed-wing aircraft in the event of sleeping-sickness epidemics. As aerial spraying projects increase in size and complexity it should become possible to attain more uniform coverage with lower dosage rates, provided that accurate track guidance systems are available.

Blackfly control techniques involving the use of aircraft have been developed in recent years and are now being utilized in the large-scale Onchocerciasis Control Programme in the Volta River Basin area of West Africa. This programme currently makes use of 5 helicopters and 2 fixed-wing aircraft to apply larvicides to rivers in the programme area and also to transport personnel for the surveillance of *Simulium* breeding sites.

Helicopters and fixed-wing aircraft fitted with "rapid release" systems are used for the application of larvicides in different types of rivers: helicopters for narrow watercourses and fixed-wing aircraft for larger rivers. As most of the breeding sites are located in narrow watercourses the use of helicopters is paramount in the programme.

Although most of the breeding sites can be satisfactorily controlled by the techniques mentioned above, there are some sites that are difficult to treat by either helicopter or fixed-wing aircraft with the present equipment. There is a need to assess other forms of transport that could serve as platforms for pesticide application equipment (see section 6.3) and to develop equipment for applying larvicides to difficult sites. The programme aircraft could also be used for the control of possible outbreaks of other vector-borne diseases in the area, in which case different types of application equipment would be required.

In general, the Committee took note of the valuable results obtained with aerial applications and considered that research should continue in the use of aircraft for this purpose. The Committee also recommended the development of simple and inexpensive equipment that could be attached to a variety of aircraft types for use in emergency situations. The equipment should be stockpiled and kept available for immediate use. In connexion with the Onchocerciasis Control Programme it was proposed that the development of pesticide application equipment for *Simulium* control should be pursued and that suitable equipment should be available in the programme area for the control of other disease vectors where necessary. In addition, in view of the lack of information on the types of aircraft available in emergency situations, it was suggested that an up-to-date list be compiled of the aircraft available throughout the world that would be suitable for use in vector-borne disease epidemics.

4. NON-CHEMICAL CONTROL MEASURES

Although chemical methods for vector control will continue to be used in the foreseeable future, the Committee recognized that there is a growing public awareness of possible harm to the environment resulting from the incorrect use of pesticides. In addition, insecticide resistance in vectors and the increased cost of chemical pesticides in recent years have brought out the need for alternative control measures. As time goes on, comprehensive vector control operations consisting of an appropriate combination of environmental, biological, and chemical methods for the suppression of vectors will become increasingly needed.

4.1 Biological control measures

Interest in the development of biological methods for the control of mosquitos has grown rapidly in recent years. Laboratory investigations have shown the potential effectiveness of a number of protozoa, bacteria, fungi, viruses, and nematodes; and field trials of some agents have apparently given highly promising results.

In general, the equipment and techniques designed for the application of pesticides are adequate for the dissemination of microorganisms and nematodes in biological control operations. However, high temperatures, shearing forces, and other factors may degrade biological control agents during application, and the Committee suggested that these factors should be examined before such agents are applied. In any event, there is no indication that microorganisms for biological control will be available for widespread field application for several years. The use of

larvivorous fish continues to be the only biological measure currently available for mosquito control on an operational scale.

Larvivorous fish are currently used by approximately 30 countries as part of their programmes for *Anopheles* control. In some countries limited success has also been obtained in the control of *Aedes* and *Culex* species as well. Massive releases of fish have been made in Iran since 1966 and in Afghanistan since 1971.

For any control programme utilizing fish, operational problems connected with their rearing, transport, and stocking must be solved. In Iran and Afghanistan rearing was done in both natural and artificial bodies of water. The depth of artificial ponds is a critical factor as fish must be protected from the cold during winter months. It was also found necessary to provide some shelter for the young fish.

For transportation of fish various methods have been used. In Afghanistan *Gambusia* were successfully carried for up to 12 hours in open containers accommodating as many as 1 500 fish at temperatures between 13°C and 18°C. In Iran more sophisticated methods were used, such as double-walled polyethylene bags of 30–40 l capacity packed in wooden boxes, each bag half filled with water and inflated with oxygen. Up to 300 fish were transported in each bag. The vehicle used for transport also carried an oxygen tank, which was used periodically to reinflate the bags. By this method it was possible to carry fish for distances of over 2 000 km. Plastic churns of 25 l capacity have also been used. In some countries fish have been transported in metal cisterns equipped with a compressor for aeration of water.

Where possible, the transportation containers should be immersed gradually in the water of the breeding place to equilibrate the temperature of the container water with the temperature of the water to be treated so that the fish can adapt to the latter before they are released. Releases of *Gambusia* can be made from a moving vehicle, from aircraft, or by hand. Application rates vary from place to place and species to species. It has been found that 2–5 fish per square metre are generally required for effective control.

Results have been encouraging in isolated localities in some countries such as Iran, where reductions in malaria endemicity were noted after the introduction of larvivorous fish.

4.2 Environmental measures

Environmental methods of vector control include source reduction, in which breeding sites are eliminated; water management, in which

water bodies are rendered unsuitable for breeding ; and other measures, such as improved housing, which are designed to prevent breeding or reduce man-vector contact.

The potential hazards of man-made and natural breeding sites for the vectors of malaria and other water-associated diseases are often of concern, particularly in irrigation and water impoundment projects. Careful consideration should be given to the correct design and operation of these projects, and investigations should be carried out to determine how existing structures can be modified and new ones designed so as to minimize breeding of vectors.

Such measures often call for increased coordination between officials responsible for vector control and other government agencies. For example, to prevent the formation of vector breeding habitats in urban areas, it is essential to secure the collaboration of those responsible for city planning and the provision of water and drainage systems. Similarly, during the construction of roads, dams, and irrigation systems in rural areas, more attention should be paid to the risk of creating breeding sites, especially in " borrow pits " and other excavations. It is desirable to incorporate a vector control component into all aspects of socioeconomic planning. The Committee took note of the experience (Annex 3) in a country where careful management of water resources resulted in the reduction of the densities of disease vectors to insignificant levels.

A careful cost/effectiveness analysis is desirable before any long-term vector control measure is selected.

At the village level, training programmes for health workers should emphasize elementary measures for vector control, such as elimination of man-made breeding sites, destruction of water-retaining debris such as tin cans, drainage of ditches, sanitary disposal of solid and liquid waste, cleansing of domestic water containers, and personal hygiene. Community participation in implementing these measures should be encouraged.

5. SAFETY CONSIDERATIONS

The Committee noted the evaluations currently being made of the safety of pesticides for public health use through the WHO Programme for the Evaluation and Testing of New Insecticides. It also reviewed recent reports of the WHO Expert Committee on Insecticides (3, 4), in which toxicological studies and possible hazards of pesticides were examined and specific safety precautions recommended.

Both the degree of human exposure to a pesticide and the pollution of the environment depend partly on the type of operation being carried out and partly on the type and manner of use of the application equipment. The Committee therefore considered the safety aspects of the different types of equipment separately.

5.1 Chemical control measures

Field experience has clearly demonstrated that spraymen, and particularly those involved in mixing, are subject to higher pesticide exposure than other types of workers in vector control operations. In one survey, 60% of all workers showing signs of significant pesticide absorption were mixers. The problem arises mainly because the products handled by mixers, such as water-dispersible powders, contain a high concentration of active ingredient. Wherever possible, semi-automatic or closed mixing systems should be used in large-scale programmes. The recent development of an efficient closed mixing system was noted and it was considered that, if such a system could be produced cheaply, the contamination arising from the handling of pesticides would be largely eliminated. The Committee proposed that studies be made on ways of reducing the hazards of contamination connected with mixing and application techniques.

The pre-packing of pesticides into small labelled plastic bags containing enough material for a single tank charge eliminates the need to weigh pesticide concentrates in the field, thereby lowering the risk of contamination and ensuring the correct application dose. This method also reduces the spillage and wastage that may occur when large mixing containers are used in the field, and minimizes the exposure of children and domestic animals. Bags, as well as other pesticide containers, should be disposed of safely (5).

Among the causes of operator contamination are poor design and poor maintenance of application equipment, which lead to valve leakage, nozzle blockage, and similar problems. Suitable filters should be used in the pesticide supply line because they reduce blockage of nozzle tips and hence the frequency with which nozzles must be washed. Multi-purpose nozzles, which require manual change of nozzle tips in order to modify spray patterns, should not be used where pesticides of relatively high toxicity are being applied.

During spray operations, and particularly during indoor application, the nozzle should be kept as far away from the operator as possible so as to minimize the risk of contamination. However, the length of the

lance is limited by the need to be able to manoeuvre it freely within dwellings. To reduce the possibility of droplets' bouncing back from the wall being sprayed, hydraulic nozzles should not be operated at pressures above 6.5 kPa.

The high concentration of pesticides frequently used in ULV applications demands special care and training in dealing, for example, with spills, leaks, and drift from equipment. More knowledge of the characteristics and fate of the pesticide particles emitted by ULV equipment should be acquired in order to be able to assess with more certainty the safety of a given method of dispersal.

It was recognized that the use of motorized equipment exposes operators to additional risks, including possible injury from moving parts and fire hazards. Fuel lines should be checked regularly and replaced as necessary to reduce the risk of leakage and ignition of fuel. It was also suggested that designers of portable motorized equipment should consider positioning the fuel tank as far away from the engine as possible and covering the exhaust with a robust guard. The reduction of noise and vibration produced by the engines driving the fan of knapsack sprayers is another requirement for the operators' safety and comfort. Ear protectors should be provided for operators whenever the noise level close to the ear exceeds 90 dB.

Protective clothing should be worn by those using or servicing pesticide application equipment. The type of clothing required depends on the physical state of the pesticide formulation being used, as indicated in the WHO Recommended Classification of Pesticides by Hazard (6). The usual protective clothing for vector control work consists of overalls or a long-sleeved shirt and long trousers, which should be washed as soon as spraying is completed. Workers such as mixers who are in contact with concentrates should in addition wear gloves. Details of protective equipment and the influence of the climate on its use have been considered by another WHO Expert Committee (4). The main object is to minimize skin exposure. In cases where it seems likely that special protective clothing will need to be worn, it is important for the equipment designer to bear this in mind and make such modifications to his design as are compatible with the wearing of personal protection.

In order to minimize the risk of injury to workers and other persons, the design of engines should be such that all moving parts are shielded and all heated parts insulated. It was recommended that manufacturers should be encouraged to modify their equipment along these lines in addition to reducing noise and vibration to the lowest levels possible and safeguarding against fuel and pesticide leakages.

5.2 Non-chemical control measures

Biological control agents, except for larvivorous fish, have not yet come into operational use in vector control programmes. Taking note of the scheme for screening and evaluating the efficacy and safety of biological agents for the control of disease vectors as contained in Annex 1 of the report of a previous WHO Expert Committee (7), the Committee considered it difficult at this stage to identify any particular safety problem connected with the use of application equipment for the dispersal of biological control agents. It observed, however, that biological control agents, both particulate and water-soluble, can contain protein and be antigenic. Consequently, contact could cause skin or respiratory irritations or elicit sensitivity reactions in individuals. This may require some modification of equipment design in the future. It may also call for the use of protective clothing such as that described above (section 5.1).

Environmental measures of various sorts, e.g., the construction of dams and establishment of irrigation systems, may influence the presence and density of vectors in positive and negative ways, in both rural and urban situations. To minimize any negative effects, close cooperation between the various authorities is essential, especially when there is a possibility that environmental measures may inadvertently create conditions that favour the breeding of rodents in towns or the breeding of other vectors both in towns and in rural areas. Sometimes environmental measures for vector control will unavoidably affect species other than target species. As a general rule, the avoidance of health problems should receive primary consideration and possible effects on the ecosystem should be considered secondarily.

6. TRANSPORT IN VECTOR CONTROL OPERATIONS

Information concerning transport in surveys and vector control operations is very limited as details are seldom provided in reports. References to vehicles in the literature are brief and rather uninformative, e.g., a "4-wheel-drive truck". Vehicles are sometimes mentioned in passing as having been used for the transport of various kinds of spraying and fogging equipment but few details are given regarding the numbers and exact types of vehicles used, the modifications that had to be made to them, the speeds at which they were driven, or the prob-

lems encountered with their use. Moreover, the transport of application equipment is only a small part of the transport requirements of surveillance and vector control operations, being overshadowed by the transport requirements for personnel and other equipment.

Although adequate transport is vital in all vector control programmes for moving application equipment, materials, and personnel, it is usually given insufficient attention. The Committee stressed the need for programme planners to assess their transport requirements in detail so as to ensure that the vehicles chosen are appropriate for the needs of the programme. One particular problem is that the need for servicing and maintenance of vehicles is always underestimated during planning.

In most developing countries vehicles must be imported, and delays in receiving them can seriously impede the progress of a vector control programme. Intervals of several months occur between the placing of the order and the arrival of the vehicle ; and further time is often lost if international boundaries have to be crossed. Similar delays occur in the procurement of spare parts for vehicles, in addition to the difficulty of acquiring the right items for the various vehicles used. It is essential that all service centres and persons responsible for maintenance be provided with workshop manuals for the vehicles under their authority. The smooth running of a workshop requires skilled manpower. To increase efficiency, drivers of vehicles may be required to perform simple maintenance when travelling in remote areas. It should be recognized that drivers are responsible for valuable equipment and they should receive adequate training so that they can perform their duties effectively. It is also important that their wages and status should be appropriate for their level of responsibility.

For large transport fleets, the locally available maintenance and repair facilities and spare parts supplies may be totally inadequate or prohibitively expensive. In such cases, separate facilities must be provided by the programme.

6.1 Wheeled vehicles

Bicycles have provided valuable service in some vector control operations, for example in urban mosquito control and vector surveillance, and the Committee felt that insufficient use is being made of them at present.

The current high prices of motor fuel and all too frequent inadequate supplies in rural areas suggest that, in many types of control and sur-

veillance operation, serious consideration should be given wherever possible to replacing motorized vehicles by bicycles. Running and maintenance costs of bicycles can be extremely low and accidents associated with their use are far less likely to result in the serious damage to personnel and equipment that almost invariably results from accidents involving motor vehicles.

Motorcycles were discussed by the Committee. One view expressed was that they could play a useful role in vector control operations, especially for liaison work. However, it was noted that motorcycles would be difficult to use in rural areas unless adequate maintenance and repair services were available.

Some of the problems connected with the use of motorcycles can be avoided if personnel using them are required to purchase the machines themselves. An allowance is then paid to the owners for the use of their cycles for duty purposes. A loan may be made to assist with the purchase of machines.

Four-wheeled motor vehicles are the most widely used form of transport in vector control programmes and, as such, may account for a significant proportion of operational costs. Four-wheeled vehicles are used for the transport of equipment and personnel and also as platforms for pesticide application equipment. It was emphasized that such vehicles must be selected on the basis of how and where they will be used. For example, 4-wheel-drive vehicles should not be bought if their use would be limited to urban areas with good road surfaces. Similarly, large vehicles may not be suitable in certain areas where roads are narrow. Whenever possible, vehicles should be fitted with auxiliary fuel tanks so as to increase their range. In addition, special modifications may be made to vehicles to suit the purposes of the control programme, for example, the provision of protective cabs and water tanks.

The Committee felt that there was a need for a small 4-wheel-drive vehicle suitable for carrying vehicle-mounted pesticide application equipment and personnel in areas that are difficult to reach.

Other ground vehicles such as the amphibious multiwheeled vehicle were considered by the Committee. Although the use of amphibious vehicles for vector control has not been extensively explored it was suggested that they could be of real value in programmes in which workers, equipment, and application machines have to be carried over rough and marshy terrain.

Various types of earth-moving vehicles are widely used in source reduction operations but these were not discussed in detail by the Committee.

6.2 Boats

Boats are in regular use in the Onchocerciasis Control Programme in the Volta River Basin area, chiefly for carrying personnel to survey breeding sites and, to a lesser degree, for applying larvicide for the control of *Simulium*. In the latter case, the turbulence created by the propeller conveniently disperses the larvicide in the water. However, treatments from boats are made only to sites that are difficult to treat from aircraft.

Boats have also been used to some extent in the control of tsetse flies in riverine habitats. Application equipment, such as foggers and aerosol generators, is mounted on the boat and insecticide is applied to the vegetation on the river banks. Insecticides for the control of adult mosquitos have also been applied to mangrove swamps with thermal fogging equipment mounted on boats, and similar larviciding operations in this type of habitat have been effective as well.

6.3 Air-cushion vehicles

The Committee recognized that air-cushion vehicles (ACVs) might be suitable in areas where other types of transport are not feasible. However, it felt that the lightweight ACVs currently available have operational limitations in that their manoeuvrability decreases with increased windspeed; under these conditions, they are difficult to operate with any degree of precision. The Committee nevertheless recommended a technical appraisal, under field conditions, of light ACVs as well as of other forms of transport such as jet propulsion boats, amphibious craft, multiwheeled vehicles, and tracked equipment.

6.4 Aircraft

Aircraft use in vector control operations, such as the Onchocerciasis Control Programme, was discussed. It was agreed that, although aircraft operations do involve considerable expense and require comprehensive technological support, overall savings in costs can often be achieved by the judicious use of aircraft in preference to other forms of

transport. Aircraft are currently used in mosquito, tsetse fly, and black-fly control operations and, to a limited extent, in mollusc control programmes. Fixed-wing aircraft are preferred when high payload and speed are needed to perform the task efficiently; they are normally less expensive to operate than helicopters. Helicopters are used when good manoeuvrability, low speed, or low-level surveillance is required or when landings must be made in unprepared terrain.

The performance of aircraft is a vital consideration when they are to be used as platforms for pesticide application equipment. It is essential to make a detailed analysis of the tasks the aircraft and application equipment are to perform, and of the conditions under which they are to perform them. Payload, stalling speed, and range are the most important factors when selecting from different types of fixed-wing aircraft, while payload, airspeed, and operational ceiling are the important factors when selecting a helicopter.

In view of the cost of operating aircraft it is essential that, at the planning stage, detailed flying schedules should be written including the location of any fuel and insecticide dumps required, the preparation of airstrips, and the establishment of hangar and maintenance facilities. The Committee stressed the importance of maintaining reliable ground-to-air radio communication between ground control teams and aircraft pilots, both for giving information to the pilot and for his use in emergencies.

7. SPECIFICATIONS

The Committee considered and approved proposed revisions to Specification WHO/EQP/1.R3 concerning hand-operated compression sprayers. The newly revised specification (WHO/EQP/1.R4) appears as Annex 2 to this report.

The Committee stressed the importance of specifications. It considered that new specifications should emphasize the performance of equipment and make use of any test procedures that may in the future be recommended by the International Standards Organization. Performance specifications are needed for the motorized knapsack mist blower and for vehicle-mounted aerosol machines. Consideration should also be given to establishing specifications governing, for example, application equipment for use on a variety of types of aircraft in emergency situations and hand-carried battery-operated sprayers.

8. RECOMMENDATIONS

The Committee made the following recommendations.

1. Many pesticide formulations may have a detrimental effect on application equipment. Tests should therefore be carried out with various formulations in current use to determine which construction materials are most suitable for application equipment.

2. The correct operation of pesticide application equipment is of great importance in vector control operations. To enable the operator to monitor the performance of equipment during use, the Committee recommended that suitable meters, gauges, and other instruments should be fitted to machines.

3. Most hand compression sprayers are not fitted with pressure regulators and pressure gauges as these items are still relatively expensive and easily damaged. A robust pressure regulator and a robust pressure gauge should be developed for use with such sprayers.

4. Most motorized pesticide applicators are powered by internal combustion engines, which frequently cause trouble in remote areas with limited maintenance and repair facilities. It is recommended that alternative power sources for applicators be investigated.

5. Nozzles for the production of aerosols are frequently large and heavy. Research should be undertaken on the design of aerosol-producing nozzles suitable for portable machines.

6. Efforts should continue to develop equipment for the production and dispersal of insecticide droplets whose size can be controlled within closely specified limits. Consideration should be given to low cost, robustness, ease of maintenance, portability, and the avoidance of operator contamination, without any concomitant reduction of efficiency in the control of the target vector.

7. To ensure that application equipment is being operated correctly and that insecticide droplets of the required size are being produced, simple and inexpensive droplet-size monitoring techniques, especially for evaluation of aerosols, should be developed for use under field conditions.

8. Because of the need for rapid action in emergencies due to vector-borne epidemics, aircraft of various types are often used as platforms for pesticide application equipment. The Committee recommended the development or adaptation of simple and inexpensive application equipment for attachment to a variety of types of aircraft, both

fixed-wing and helicopters. This equipment should be stockpiled and kept available for use in readily accessible places.

9. The Onchocerciasis Control Programme in the Volta River Basin area of West Africa makes use of aircraft primarily for the control of the onchocerciasis vector, *Simulium damnosum*. So that the same aircraft can be used to deal with possible vector-borne disease emergencies in this area, the programme should be supplied with aircraft application equipment suitable for the emergency control of other vectors.

10. Aircraft are not always readily available when an epidemic of vector-borne disease occurs. The Committee recommended that an up-to-date list of available aircraft in different parts of the world should be maintained so that suitable aircraft can be located quickly.

11. Development work on the specialized equipment used to make aerial pesticide applications for the control of blackfly larvae should continue so as to improve its accuracy and efficiency.

12. Since the evaluation of different vector control techniques and pesticide application equipment in the field depends on the availability of reliable means of sampling vector populations, the Committee recommended that research should be undertaken to develop improved devices for insect sampling, especially for the detection of low population densities.

13. In view of the fact that the effectiveness of vector control equipment can be ensured only by proper maintenance and repair procedures, training courses in these procedures should be organized for equipment operators and mechanics. Such courses will require the development, in collaboration with equipment manufacturers, of various types of training aids and training manuals in vernacular languages.

14. In the case of insect vectors inhabiting forest and dense woodland, control is restricted by the limited penetration of these habitats by insecticide droplets. In addition to the density of vegetation, meteorological factors and droplet size affect the efficacy of pesticide application. The Committee recommended that pesticide applications of different average droplet size be studied in the field in relation to these factors to compare their effectiveness in controlling vectors.

15. Many types of pesticide application equipment are used in both public health and agricultural operations. The Committee recommended that purchasing agencies, for example national health and agricultural authorities, should coordinate their activities so as to obtain favourable price quotations from manufacturers. Further economies could also

result from channelling orders through such international organizations as WHO, FAO, and UNICEF.

16. Environmental methods of vector control, such as source reduction, water management, and housing improvement, have been used successfully in many areas. Consideration should be given to increasing the use of such methods in vector control programmes.

17. In view of the successful use in some countries of larvivorous fish for the control of mosquito larvae, the Committee recommended the development of equipment to facilitate the rapid production, safe transportation, and efficient dissemination of large numbers of such fish for use in vector control operations.

18. Biological control agents may be degraded during application by shearing forces, high temperatures, and other factors. The suitability of application equipment should therefore be determined before such agents are applied.

19. Man-made structures affecting the movement and storage of water may influence the breeding of many vector species and reservoirs of disease. The Committee recommended that investigations should be undertaken to determine how existing structures might be modified and new structures designed so as to minimize breeding of vectors.

20. Studies should be made to find ways of reducing the risk of serious contamination of workers during the mixing of insecticide formulations and the filling of application equipment.

21. The operators of motorized pesticide application equipment may be contaminated by leakages of pesticide and fuel and are frequently exposed to excessive noise and vibration. Manufacturers should be encouraged to improve the design of their equipment so as to minimize these hazards.

22. Transport for personnel, materials, and pesticide application equipment is an essential component of most vector control programmes. The Committee stressed the need for programme planners to make a detailed assessment of their transport requirements to ensure that the means of transport chosen are appropriate for the specific needs of the programme.

23. Considering the operational difficulties of gaining access to certain areas for vector control operations, the Committee recommended the technical appraisal and, where indicated, the further development of such forms of transport as air-cushion vehicles, air and liquid jet-

propulsion boats, and amphibious craft as well as multiwheeled and tracked equipment.

24. In view of the use made of motorized knapsack mist blowers and vehicle-mounted motorized aerosol generators for vector control, the Committee recommended that WHO should produce interim specifications for these two types of equipment. Specifications should be of the "performance" type so that manufacturers will understand clearly what is required of their products.

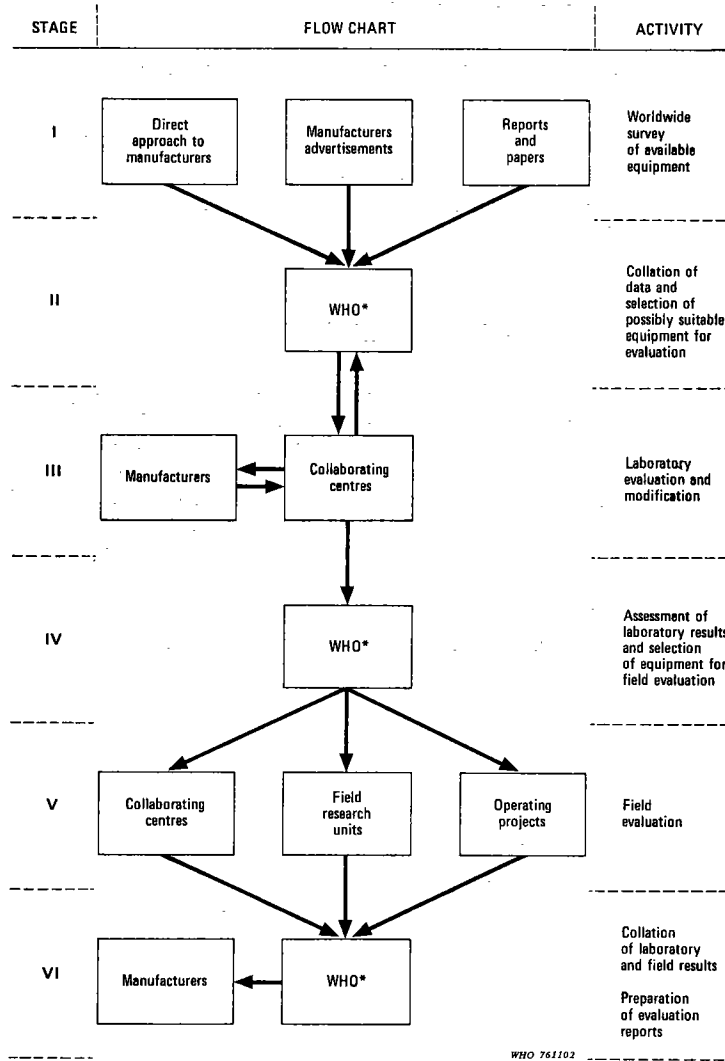
25. WHO should promote the use of the collaborative scheme for the evaluation and testing of pesticide application equipment outlined in Annex 1. WHO's activities in this field should be closely coordinated with those of FAO.

ACKNOWLEDGEMENTS

The Committee acknowledges the special contributions made during its deliberations by the following members of the WHO Secretariat: Mr R. Bahar, Regional Office for the Eastern Mediterranean; Mr D. A. T. Baldry, Vector Biology and Control; Mr F. E. González-Valdivieso, Regional Office for Africa; Mr T. Huber, Supply Services; Dr R. Le Berre, Onchocerciasis Control Programme; Dr D. Muir, Malaria and Other Parasitic Diseases; Dr C. Pant, Vector Biology and Control; Mr H. Rafatjah, Vector Biology and Control; Mr D. J. Schliessman, Regional Office for the Americas; Dr A. R. Stiles, Vector Biology and Control; Dr M. Vandekar, Vector Biology and Control.

Annex 1

OUTLINE OF WHO PESTICIDE APPLICATION EQUIPMENT EVALUATION SCHEME



WHO 761102

* All inquiries and correspondence relating to equipment evaluation should be addressed to Equipment, Planning and Operations, Division of Vector Biology and Control, World Health Organization, 1211 Geneva 27, Switzerland.

REVISED SPECIFICATION FOR COMPRESSION SPRAYER,
HAND-OPERATED ^a

Since 1970, when Specification WHO/EQP/1.R3 was approved by the WHO Expert Committee on Insecticides (1), a number of developments have taken place and considerable experience has been gained with hand-operated compression sprayers. In view of these developments, the WHO Expert Committee on Vector Biology and Control considered and approved the following revisions for inclusion in Specification WHO/EQP/1.R3.

Most of these changes are not extensive, and the Committee accordingly decided simply to list them rather than issue the newly revised Specification WHO/EQP/1.R4 in full. To enable the reader to identify the changes more readily, all newly added or revised parts of the Specification are printed below in *italics*.

Section numbers, paragraph numbers, and line numbers refer to those in Specification WHO/EQP/1.R3 as it appears on pages 91-115 of the second edition of *Equipment for vector control* (8).^b

* * *

1.2 Materials of Construction

Paragraph 4, line 3 : delete the word "metal".

Paragraph 4, last line : "... brass, bronze, copper, or Monel" should read "... brass, bronze, copper, Monel, *or plastics*".

Paragraph 5, first line, should read : "*If made of stainless steel* all joints ...".

1.4 Dimensions

Last line : "69 cm" should read "70 cm", and "21.6 cm" should read "22 cm".

1.5 Weight

Line 2 : "6.8 kg" should read "7 kg".

^a Specification WHO/EQP/1.R4, approved 13 September 1976 by the WHO Expert Committee on Vector Biology and Control.

^b A copy of Specification WHO/EQP/1.R3 may be obtained on request to Equipment, Planning and Operations, Division of Vector Biology and Control, World Health Organization, 1211 Geneva 27, Switzerland.

1.6 Tank

1.6.1 Leakage

Line 2: "kN/m²" should read "kPa".

1.6.2 Fatigue

Line 2: "kN/m²" should read "kPa".

1.6.4 Strength under hydrostatic pressure

Last line: "kN/m²" should read "kPa".

1.7 Tank Fittings

1.7.1 Fastenings for lance

Paragraph 3, first line, should read: "Samples shall withstand the drop test *as described* ...".

1.7.2.5 Pressure gauge

This paragraph should read: "A back-mounting pressure gauge, preferably of the diaphragm type, with a scale reading from 0 to 700 kPa shall be fitted. The body material shall be brass, bronze, or other metal *or material* having equal or superior corrosion resistance and strength. The sensing element chamber must be 'non-pocketing' to prevent interference with the proper operation of the sensing element by the deposition and accumulation of spray materials. *In the case of diaphragm type*, the inlet port shall have an easily removable filter assembly, *or other means to prevent the entry of suspended material*. The dial cover shall be shatterproof and moisture-proof and permit easy reading of the tank pressure. A sample gauge should meet the specified requirements when subjected to tests described in section 2.14."

1.7.3 Filler hole

Line 3: insert "*preferably*" after the word "tank", and *delete* "of the 'plumber's' type".

1.8 Pump

1.8.1 Construction

Lines 1-2 should read: "The pump cylinder shall be of seamless or electrically welded construction, *if made of stainless steel or other metal*."

Line 4: "kN/m²" should read "kPa".

Last line should read : "... to facilitate *reassembly* of the plunger cup."

1.8.2 Capacity

Line 2 : "kN/m²" should read "*kPa*".

1.8.3 Check valve

Line 3 : "kN/m²" should read "*kPa*".

1.8.4 Plunger shaft

First sentence should read : "The plunger shaft *may be* of steel and *be* either a solid rod or a tube." Delete the next 2 sentences (lines 2-4), i.e. "*If a hollow tube, ... 9.5 mm in diameter.*"

Line 8 : "13 mm" should read "*15 mm*".

Line 9 : "0.45 kg" should read "*0.5 kg*".

After last sentence of paragraph, insert : "*This test shall be done after 10 full pressurizations of the tank to 385 kPa.*"

1.8.5 Plunger cup

Line 4 : "1.6 mm" should read "*1.5 mm*".

1.8.7 Handle

Lines 2-3 : "19 cm" should read "*20 cm*" and the words "not less than 3 cm in diameter" should be *deleted*. The full sentence should read : "*The T-type shall be a cylindrical tube not less than 20 cm long.*"

1.8.8 Handle locking device

Lines 2-3 : "lowest operating position" should read "*nearest to the lowest operating position*".

1.9 Dip Tube

This paragraph should read : "The dip tube shall be constructed of *brass, stainless steel, plastic, etc., and shall extend to within approximately 1 cm* of the bottom of the tank. The end of the tube within the tank shall be cut at an angle of 45° to prevent blockage. The dip tube shall be *securely* supported at the point where it emerges from the tank and at a point near its lower end within the tank."

1.10 Strainers

Delete the first 2 sentences and replace them by the following : "*One or two strainers may be provided. Two strainers shall be of equal*

dimensions located at different points easily accessible in the discharge line between the entry to the dip tube and the entry ports of the cut-off valve. If one strainer is provided it may be located in the cut-off valve. The strainers shall be made of Monel, stainless steel, plastic, bronze, or any material of equal or superior durability and non-corrosiveness.

Line 11 : "2.4 mm" should read "2.5 mm".

1.11 Hose

First sentence should read : "Hose for general use shall be of *natural or synthetic rubber or vinyl and shall be resistant* to the pesticide formulations or oils to be used, as specified by the purchasing agency."

Requirement (1) : delete column for plastic.

Requirement (2) : delete column for plastic ; "2800 kN/m²" should read "2800 kPa".

Requirement (3) : delete column for plastic ; "2800 kN/m²" should read "2800 kPa" and "1000 kN/m²" should read "1000 kPa".

Requirement (4) : delete column for plastic ; "455 kN/m²" should read "455 kPa".

1.12 Hose Connexions

Line 5 : "kN/m²" should read "kPa".

1.13 Cut-off Valve

1.13.1 Construction

Line 3 should read : "... readily accessible for *frequent* cleaning...".

1.13.5 Leakage

Under (a) and (b), "kN/m²" should read "kPa".

1.14 Lance

1.14.1 Description

Lines 8-9 should read : "... highest designated operating pressure. *As an option of purchase*, a gasket may be used to ensure a tight fit."

1.15 Nozzle

Heading should read : "Nozzle (*Flat Fan Jets*)."

1.15.1 Description

Last sentence should read : “*At the option of the purchaser, gaskets of polyethylene or other materials may be used.*”

1.15.3 Dimensions

Heading should read : “*Dimensions of the tip.*”

1.15.5 Performance

Heading should read : “*Performance of the tip.*”

1.15.5.1 Initial performance

Footnote 3 : “*kN/m²*” should read “*kPa*”.

1.15.5.2 Standard erosion performance

Delete last sentence of first paragraph and the remainder of section 1.15.5.2. Insert in their place : “*The tips shall be tested at 4-litre intervals for discharge rate and liquid-volume distribution patterns according to sections 2.11 and 2.12, until they are abraded to the point where :*

(a) *Discharge rate has increased beyond the limit¹ allowed by the purchaser.*

(b) *Distribution pattern has deteriorated beyond an acceptable level. The pattern is unacceptable when :*

(i) *the width of the plateau is less than 65% of the base ;*

(ii) *the heights and depths of peaks and valleys in the distribution pattern across the plateau exceed $\pm 30\%$ of the plateau height ;*

(iii) *the pattern has uneven slopes with peaks or valleys reaching the plateau or the base.”*

1.16 Gaskets

Line 3 : “*kN/m²*” should read “*kPa*”.

Line 5 should read : “*... recessed into the parts on to which the joints are made ...*”.

1.17 Optional Items

1.17.4 Constant-pressure regulator

Line 4 : “*kN/m²*” should read “*kPa*”.

¹ “*This limit may vary in different programmes with the type of insecticide, its formulation and cost, and with the type and cost of the nozzle tips used.*”

2.1 Tank Leakage Test

Line 5: "kN/m²" should read "kPa".

2.3 Tank Impact (Drop) Test

Line 4: "kN/m²" should read "kPa".

2.4 Strap Drop Test

Line 3: "kN/m²" should read "kPa".

2.9 Cut-Off-Valve Reliability Test

Paragraph 1, lines 3 and 11: "kN/m²" should read "kPa".

Paragraph 2, lines 2 and 11: "kN/m²" should read "kPa".

2.10 Lance Strength Test

Last line should read: "... leak, *bend excessively*, or be otherwise unusable ...".

2.12 Nozzle Liquid Discharge Rate Test

2.12.1 Test apparatus

Paragraph 4, line 2: "kN/m²" should read "kPa".

2.12.2 Test procedure

Paragraph 1, line 3: "kN/m²" should read "kPa".

2.15 Standard Nozzle Tip Abrasion Test

Heading should read: "*Standard Nozzle Tip Erosion Performance Test.*"

2.15.3 Discharge through nozzle tips

Heading should read: "*Test procedure.*"

Paragraph 1, line 2: "kN/m²" should read "kPa".

Add a new paragraph 3 as follows: "*Tubes in the liquid-volume test at the ends of the spray base that receive less than 1 ml shall be omitted from the performance test.*"

2.15.4 Test of nozzle tips

Delete this section.

**EFFECT OF NATIONAL WATER MANAGEMENT POLICIES
ON VECTOR POPULATIONS IN ISRAEL ^a**

Israel is a semi-arid country with rainfall averaging 500 mm a year between November and March. Its water development and management policies were not designed for vector control purposes. However, they have led to a reduction in disease vectors associated with surface water as a result of the following measures.

- The development of groundwater resources, together with extensive drainage schemes, has brought about the drying up of all swamps and ponds and the elimination of water flow in streams during the dry season. Water is stored underground by the artificial recharging of aquifers, which eliminates the need for surface-water reservoirs. This has resulted in the disappearance of the majority of habitats suitable for mosquito breeding.
- Irrigation policies have aimed at the more efficient use of water in agriculture. The replacement of gravity irrigation by sprinkler or drip techniques has almost eliminated man-made breeding sites that were previously responsible for considerable health hazards.
- The supplying of tap water to 98% of households has done away with mosquito breeding previously associated with domestic water storage. This policy was put into effect in conjunction with the provision of wastewater disposal systems in the interest of general environmental sanitation. As an extension of this policy the secondary treated sewage effluent is being used for irrigation, thus achieving general environmental improvement and water economy.

In addition, herbicide applications are made in the remaining water bodies to remove vegetation from the edges. This measure has cut the total cost of vector control by 30–40%. Vector control operations are carried out by means of locally made dual-purpose equipment that can

^a The Committee considered that the water management policies outlined here, while not universally applicable, could be effective in other semi-arid countries in controlling disease vectors.

be used either in agriculture or in public health. Herbivorous fish are also used for the control of algae in large water reservoirs to achieve further improvement of water quality.

The use of irrigation in agriculture can require the introduction of pesticides, including herbicides, into the water systems, possibly endangering the potable water supply. Legal, administrative, and technical means are being adopted to prevent this potential health hazard.

REFERENCES

1. WHO Technical Report Series, No. 465, 1971 (*Application and dispersal of pesticides* : eighteenth report of the WHO Expert Committee on Insecticides).
2. DAVIES, H. *Tsetse flies in Northern Nigeria*, 2nd ed. Ibadan, Ibadan University Press, 1967.
3. WHO Technical Report Series, No. 356, 1967 (*Safe use of pesticides in public health* : sixteenth report of the WHO Expert Committee on Insecticides).
4. WHO Technical Report Series, No. 513, 1973 (*Safe use of pesticides* : twentieth report of the WHO Expert Committee on Insecticides).
5. WHO Technical Report Series, No. 227, 1962 (*Toxic hazards of pesticides to man* : twelfth report of the Expert Committee on Insecticides).
6. *WHO Chronicle*, 29 : 397-401 (1975).
7. WHO Technical Report Series, No. 561, 1975 (*Ecology and control of vectors in public health* : twenty-first report of the WHO Expert Committee on Insecticides).
8. *Equipment for vector control*, 2nd ed. Geneva, World Health Organization, 1974.